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Advanced Research Projects Agency

COMMANDERS DIGEST

VOL. 14, NO. 6/AUGUST 9, 1973

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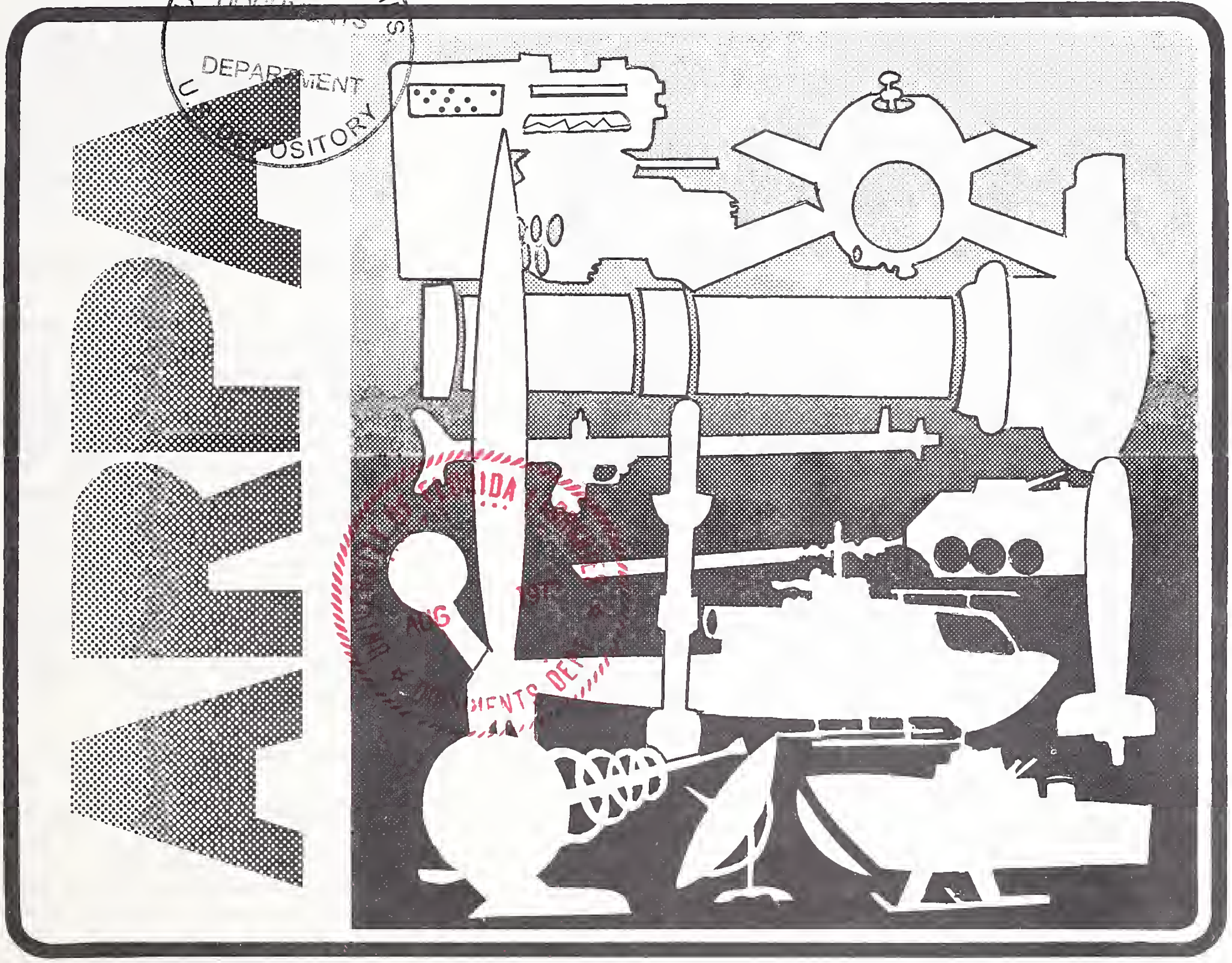

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What ARPA Does for Defense

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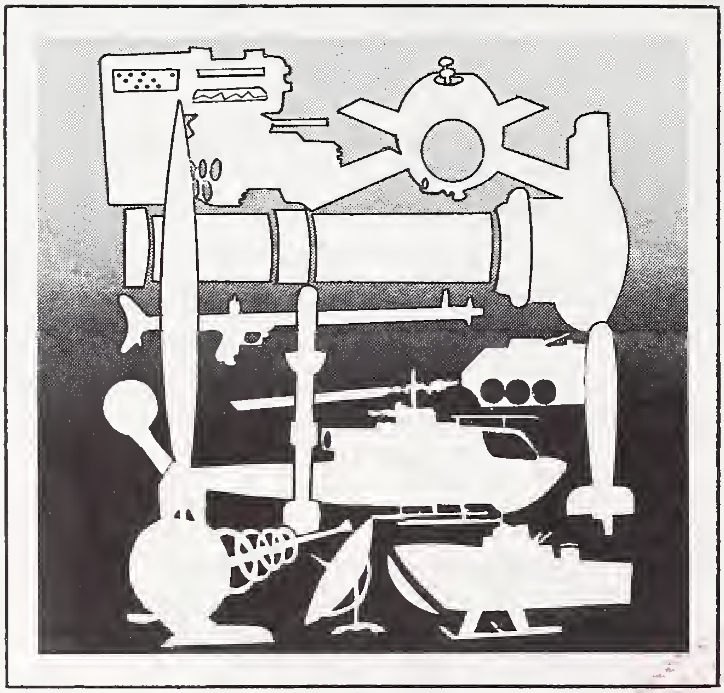
How DoD Advances R&D Technology

—pg. 4



ARPA

In 1972, ARPA became a separate defense agency after 15 years of achieving priority scientific objectives in support of National defense. The agency continues as a flexible management tool of the Secretary of Defense.

Among the many Defense reports presented to this current session of Congress was a comprehensive statement by the Director of the Defense Advanced Research Projects Agency, Dr. Stephen Lukasik, before a House Armed Services subcommittee. Dr. Lukasik's full statement was delivered on June 5, 1973. In this excerpted version, Commanders Digest has concentrated on the Defense overview, with a particular eye toward the implications of national policy. Commanders interested in specific project reports should refer to the Congressional Record of June 5.

Defense Advanced Research Projects Agency (ARPA), is essentially a management tool of the Secretary of Defense, a flexible responsive Research and Development (R&D) organization having a broad charter to take on such tasks as the Secretary requires to achieve priority scientific objectives in support of national defense. ARPA was established in early 1958 to prevent the kind of technological surprise presented by the Soviet satellite launching, an accomplishment within the capability of then-current U.S. technology but not achieved because no organization had it as an assigned job. In 1972, the scope and thrust of ARPA's research program was validated in a new DoD directive establishing ARPA as a separate Defense agency. With a broad charter, with a constant succession of new technological opportunities, and with a continuing number of assigned tasks, ARPA might easily have grown by accretion in an unlimited way.

ARPA has successfully avoided becoming institutionalized, however, and is, after 15 years, slightly smaller than it was when it was created. ARPA has done this by employing three management techniques. First, there has been **an emphasis on quality over quantity in staff and recruitment** of senior technical people from industry, universities, and not-for-profit organizations for relatively short tenures. Second, ARPA has operated with **minimal administrative or experimental facilities.** Contracts are written with the best available technical talent in the country and are administered by other DoD (and, where appropriate, non-DoD) organizations; existing experimental facilities are used whenever possible. Third, technical and funding responsibility for **successful ARPA programs are transferred from ARPA** to a development or operational agency as soon as possible, generally after 3 to 6 years.

ARPA programs are formulated within a context of limited Defense spending, a climate of ongoing strategic arms negotiations, determined Soviet efforts to upgrade their forces, and the need to maintain the viability of our strategic deterrent. All ARPA programs have at least one of the following characteristics:

- Have a risk too high to survive the Service budget process but with a sufficiently high potential payoff, if successful, to warrant support; often only a feasibility demonstration is required to secure Service support;
- Have a broad utilization within DoD, i.e., multi-Service;
- Require study of potential DoD applications in order to assist in the assignment of the program or mission to a single Service;
- Address technology areas where major advances are sought; leave evolutionary and product-improvement R&D to the Services; and
- Be of sensitivity or interest that central management within OSD is required.

ARPA interacts broadly within DoD in the formulation and conduct of its research program. These interactions can be grouped into several main classes. For the determination of DoD problems and program formulation, the most useful relationships are those with groups having a breadth of view similar to ARPA's, especially the Office of the Secretary of Defense (OSD) and the Unified Commands.

Pentagon Links

Within OSD, the major relationship is with the Director, Defense Research and Engineering (DDR&E) for program review and coordination with Service programs. Other Pentagon offices which provide significant inputs to ARPA are the Assistant Secretaries for Telecommunications, International Security Affairs, Manpower and Reserve Affairs, Intelligence, Systems Analysis (now the Office of Defense Program Analysis and Evaluation), and the Assistant to the Secretary for Atomic Energy. Contact with the Unified Commands takes place primarily with the European, Pacific and Strategic Air Commands. Contact with the first two is enhanced by the presence of newly established ARPA representatives in those headquarters.

The Defense agencies represent sources of both information and guidance for ARPA programs as well as contracting and monitoring assistance. These are primarily the Defense Intelligence Agency, Defense Nuclear Agency, Defense Communications Agency, and the Defense Security Assistance Agency.

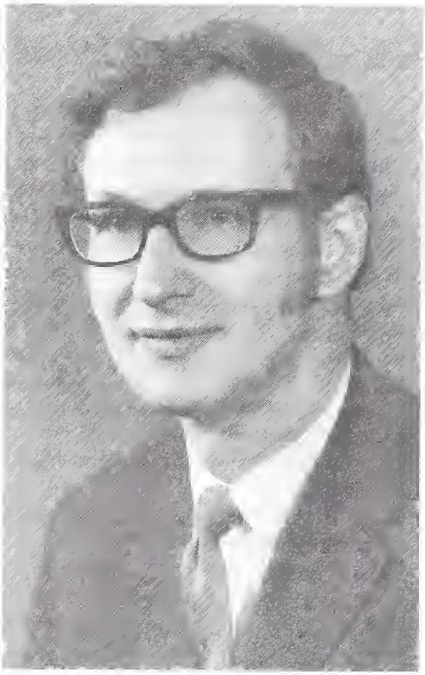
ARPA contracts are administered by about 69 Defense organizations, mainly in the three Services, and about 8 non-Defense organizations. Aside from contracting and monitoring services, these organizations form the backbone of the ARPA program transfer-management technique. The contracting organizations are selected initially on the basis of their in-house technical capability as well as with a view to eventual program transfer. By writing and monitoring the ARPA contracts, these organizations have an opportunity to learn the technology, guide the program along lines of greatest Service need, coordinate the work with related Service programs, eliminate possible redundancies, feed results from ARPA programs into Service R&D and operational activities, and prepare to take over fiscal and technical responsibility for the ARPA program at an appropriate point.

The criteria and procedures for program implementation keep ARPA in the forefront of DoD's Research, Development, Test and Evaluation (RDT&E) activity. This ensures achievement of the technological quality to maintain a significant array of options in the use of U.S. military forces and to minimize the likelihood of technological surprise.

DR. STEPHEN J. LUKASIK

DIRECTOR

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY



Dr. Stephen J. Lukasik was appointed Director, Defense Advanced Research Projects Agency in April 1971. Prior to that, he served as Acting Director since January 1971, Deputy Director of ARPA since June 1968, and as Director of Nuclear Test Detection, ARPA, since April 1966.

Before coming to ARPA, Dr. Lukasik was Research Associate Professor of Physics, Head of the Fluid Physics Division of the Davidson Laboratory, and Acting Director of the Computer Center at the Stevens Institute of Technology, Hoboken, New Jersey. From 1955 to 1957 he was a scientist with the Westinghouse Electric Corporation where he did research work in nuclear physics.

Dr. Lukasik received his Bachelor of Science degree from Rensselaer Polytechnic Institute in 1951 and his Doctorate in Physics from the Massachusetts Institute of Technology in 1956.

ARPA Technology Provides American Defense With

ADDED INSURANCE

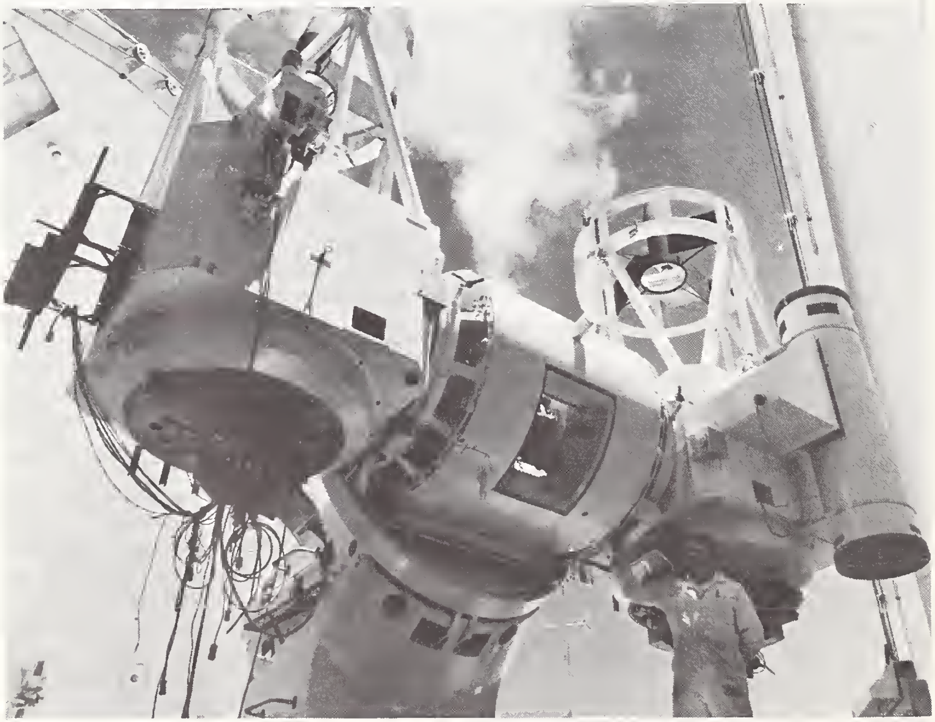
The United States must maintain military technological superiority as insurance against a weapon development that changes the current military balance. Basically, technological superiority means having the fundamental knowledge needed to know what to do and how to do it when we are confronted with a new threat. This involves remaining in the forefront of military science and technology and, where necessary, encouraging the development of those areas where current or future problems require for their resolution as yet undiscovered techniques and insights.

Optical Signals

ARPA is developing the technology of integrated optical circuits which promises to have a great impact on local communications systems such as those within aircraft or ships. Commanders are probably familiar with the "light pipe" concept: light introduced into a transparent rod or flexible fiber at one end emerges from the other end, no matter how the rod is bent or twisted. By this means, optical signals can be conducted from point to point, much as if they were electrical signals in a wire. In addition to ultralow loss fiber materials, ARPA is working on devices for generating and receiving the optical signals, as well as controlling and modulating them. Systems such as DoD envisions will have several major advantages; optical communications of this type can easily be made secure and are immune to radio frequency and other electromagnetic interference. They are very lightweight and compact as compared to electrical wired systems and can be used at information rates much higher than attainable with electrical systems.

Another project in the optical area is concerned with the development of radiation detector materials. Here ARPA is making a basic research effort to improve military night vision capabilities. In the night sky, there is a relatively large amount of infrared light which results from solar radiation exciting molecules in the upper atmosphere. This light is in a wavelength region where currently available image intensifiers have very low efficiency. Recently improved semiconductor technology has become available which may make it possible to combine new field-enhanced solid state photocathode concepts and materials with the precise manufacturing methods used in current image intensifiers. DoD expects this research to result in a hundred-fold improvement in the conversion efficiency of these devices. This should have the practical result of increasing the useful range of night vision viewers by a factor of ten. The work also includes development of detectors for laser illuminators in the same wavelength region for eye-safe spotting and target designation.

A wideband holographic recorder for use with high resolution images is being designed and critical components are being tested. This recorder will be useful with the electronic camera and in many other applications where very high data rates are employed.



ADVANCED COMMUNICATIONS—New communications systems utilizing space-age optical systems are among a variety of advanced research and development projects managed by the Advanced Research Projects Agency. ARPA was established in 1958 to insure the superior technology of U.S. weapons and systems. It became a separate Defense agency in 1972.

By **DR. STEPHEN J. LUKASIK**

Director, Defense Advanced Research Projects Agency

ARPA has been engaged for two years in a program of research on the physics of rocket plumes. The program in FY 74 is oriented to increasing our fundamental understanding of the fluid mechanics, chemistry, and optical physics. This program provides a technical basis for preventing technological surprises that might negate U.S. optical defensive systems.

Finally, in the area of optics the project in Midcourse and Special Infrared Optics explores the areas of technology needed for advanced space surveillance, and defensive systems, in the long wavelength infrared (LWIR), visible, and ultraviolet portions of the spectrum. The program includes: sky, celestial, and earth limb measurements at operational sensor sensitivities which are defining for the first time the LWIR background environment. An earth limb measurement spectrometer with twenty-seven spectral bands and with an exceptional ability to reject spurious radiation, a critical requirement for definitive results, were to be completed in FY 73. In FY 74, ARPA will conduct rocket probe flights of high sensitivity prototype sensors. Active and passive measurements will continue to be performed and program definition studies for a synchronous satellite detection sensor are continuing. It is anticipated that this program will make major multi-Service contributions.

In the area of Surface Effect Vehicles (SEV), ARPA's program will be substantially completed in FY 74. ARPA has determined that a great number of useful arctic SEV missions can be performed by vehicles of the 500-ton gross weight size, and the technology developments completed thus far are adequate for the design of SEVs in this range with cruise speeds of about eighty knots. In the coming year, ARPA will solve problems in the areas of skirt wear and failure mechanisms, drag determination, and vehicle dynamics. The obstacle detection system will be completed early in the following fiscal year. The technology advances already made in skirt technology, dynamic analysis, maneuver and control systems, and structures will enable ARPA to prepare preliminary design packages for 150-ton and 500-ton SEVs prior to the end of FY 74. The design packages will include a specification of requirements, parametric analyses to select vehicle configurations and characteristics, model test data, and cost estimates for detailed vehicle design and fabrication. This material will permit the Services to prepare realistic specifications for SEVs required for various military missions.

Ecology

Turning now to a different area of applied science, ARPA will continue research in numerical simulation of the atmosphere during FY 74. The aim of this work is to develop a capability for the quantitative prediction of the climatic effects of any major human action. As scientists become more aware of the sensitivity of our environment to man's ever-increasing demands, this field of investigation becomes ever more important. Indeed, a relatively minor variation in climate can be as damaging to a nation as an overt act of war. Man's increasing boldness in modifying the earth by pumping pollutants into the atmosphere, creating new lakes and seas, etc., may well have unforeseen and damaging climatic consequences for our own country. ARPA's program is aimed at developing a capability to forestall possible threats to national security by predicting them, exposing them to scrutiny, and thereby deterring injudicious acts by other nations.

The ecology program is also expected to have worthwhile fallout benefits in other Defense applications. ARPA is, for example, working with the Navy to test the applicability of ILLIAC IV, the ARPA Network, and climate models in support of day-to-day military operations. We expect that many of the meteorological findings and numerical methods developed in the program will be valuable to the military and civilian weather services. Also, the climatological data base developed for the program will be used extensively for evaluation of projected military systems and operations.

Non-Hardware Aspects

Thus far, this article has been dealing with technological superiority in terms of advanced hardware and material capabilities. In broader perspective, there are other important components of national security that do not manifest themselves in hardware. These are the processes, procedures and capabilities used in planning and developing our forces and in implementing national security policies. Clearly, maintaining technological superiority in the area of how-we-do-things is just as important as maintaining superiority in hardware. The kinds of functions referred to in speaking of the "how" of national security include decision-making, the development of accurate information to support effective decisions, and long range planning and forecasting activities.

In an effort to improve Defense decision and supporting intelligence functions, ARPA plans to continue a program of research concerned with the application and further development of quantitative decision theory. It is obvious that the factors bearing on national security decision problems are extremely complex. There are usually many relevant and conflicting factors to be assessed in reaching a decision, and this assessment is often subjective. An alternative to completely intuitive decision-making is provided by quantitative decision theory. This is a formal mathematical structure for logically choosing between alternative courses of action, a technique which provides a means for applying the same analytical discipline to judgmental tasks that are routinely brought to the more technical aspects of a problem.

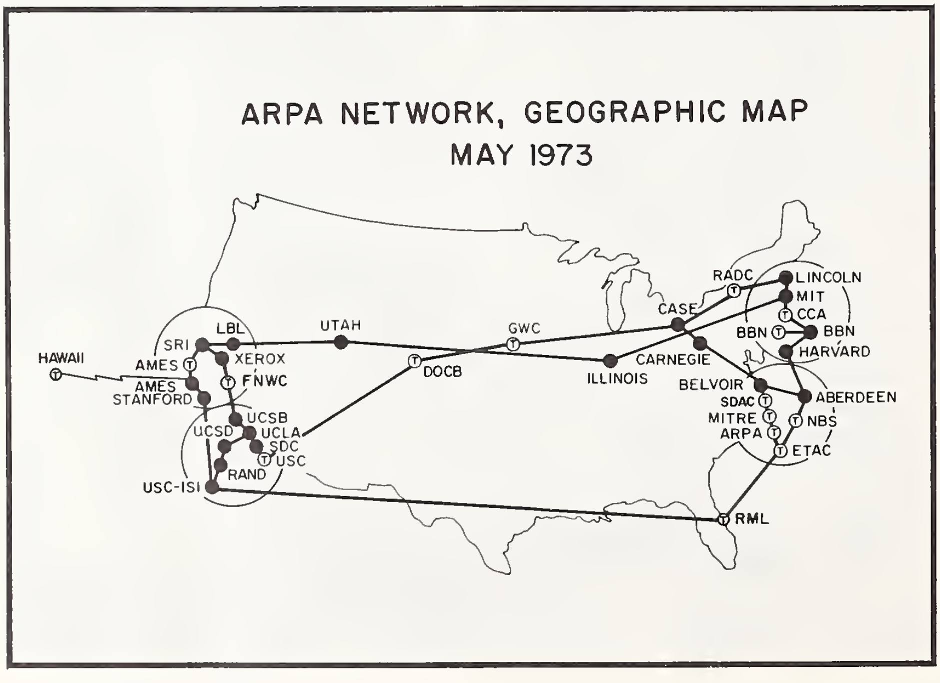
Decision-theory, in its present stage of development, has proved to be useful in the limited circumstances in which applications have been attempted. Much more can be done, however, in increasing the utility of these techniques and in advancing our general capability. The ARPA program has both applied and basic research components. In applied activities, ARPA supports decision-theory experts in working with Defense Intelligence Agency (DIA) analysts in the development and expression of intelligence estimates in quantitative terms. ARPA is also engaged in joint activities with other elements of DIA and the National Security Council (NSC) staff in applying these techniques to decision, problems involving resource allocation and selecting among alternative national security policy options.

Another area of ARPA-supported research designed to maintain an important element of technological superiority focuses on improving methods for long and short-range strategic forecasting. At present, forecasting, even in the very near term, is a very uncertain process. We do not now understand the dynamics of international relations and conflict well enough to forecast the future. Neither do we understand well enough those trends or events to measure as indicators of national security futures. In an effort to improve the situation, ARPA has initiated research in this very difficult area. The approach being employed builds on earlier ARPA work in quantitative political science in which large computer-based sets of data on international events were developed. ARPA is now engaged in research which seeks to translate selected portions of that data into quantitative indices relevant to strategic planning and to indications and warning activities. The indices under development incorporate such information as the number of conciliatory gestures between states over time, the number of minor conflicts, threat behaviors, etc. Since the indices are quantitative expressions, as opposed to qualitative judgments, there are a number of advantages; most importantly, powerful statistical techniques can be brought to bear in the search for relationships relevant to long range strategic planning activities.

ARPA is also continuing efforts in strategic early-warning analysis to develop methods for quantifying and correlating indicators to give a more timely and confident recognition of unfolding strategic events. An analysis of the strategic warning process shows that it is generally reactive in nature and depends on the manual processing of very high levels of message data. To offset these deficiencies, ARPA has developed a concept of continuous comparison of incoming data with formal criteria, quantitative measures of foreign activity, and the ability to correlate selected indicators to increase the visibility of military exercises, advanced alert postures, and force-level changes. The concept has been demonstrated in a limited way, using actual intelligence data; this demonstration verified the algorithms used and the attractiveness of computer-based systems in a realistic military indications and warning environment. In FY 74, ARPA will complete a joint ARPA/Air Force program and extend the work by integration of socio-economic and political indicators into the structure as well as including third world indicators. The most important aspect of this program is the use of strategic-warning information for early tactical warning. It is hoped that by correlation processing, DoD will be able to provide a credible warning of hours or days so that deterrent actions can be instituted and crises or confrontations mitigated.

Moving to the discussion of some very advanced work in information processing, ARPA, by pursuing a program of basic research in what is called "intelligent systems," lays the groundwork for much applied research and development in the field of computer science. The major goal of this effort is to build automatic linguistic, visual, manipulative, and problem-solving systems which can be controlled by people to perform tasks which are too complex or would take too long for personnel to do reliably or efficiently.

In vision research, ARPA use TV and other sensors such as laser range-finders to input a scene to the computer and interpret it. Fundamental problems being addressed include how to distinguish objects from their background, how to recognize objects from different views; and how to use color, texture, and shadow information to aid the recognition process. Natural language research deals with the extraction of meaning from English text, particularly in query systems and in control systems. The emphasis is on understanding the intent of the text, even if the text is ungrammatical or fragmented. Current work with manipulators is using force-feedback mechanisms to detect physical constraints. For example, it is possible now to perform simple assembly operations automatically. In another ap-


ARPA NETWORK, GEOGRAPHIC MAP
MAY 1973

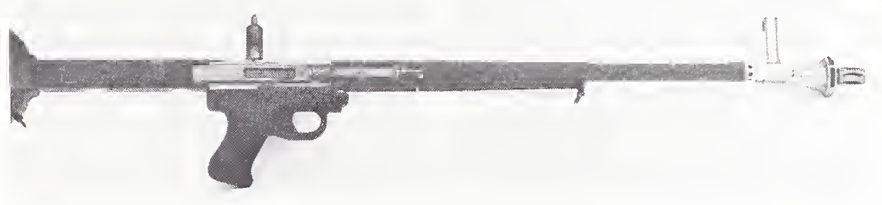
plication, many problems involving differentiation, integration, differential equations, limits of series, and algebraic reduction can be solved symbolically but frequently entail very complex formula manipulations and some trial-and-error exploration of possible solutions. These tasks are error-prone and extremely tedious for human beings, and very substantial improvements have been achieved by automating many of them.

Intelligence Applications

Using vision-based systems, it may be possible to automate mapmaking almost completely and improve the gathering and analysis of intelligence information. Using results of both vision research and manipulator development, it may be possible to automate the production, test and repair of very small objects and to substantially reduce the cost of producing prototypes, small quantities, and many variants of any object. Research in mathematical deduction has produced a system to analyze mass spectrograms and another system to solve algebra, calculus, and differential equations problems. Continued research in this field will have a significant impact on all of the physical science research and engineering in this country.

Concerning the ARPA program in speech understanding, the objective of this research is to develop prototype systems capable of responding meaningfully to spoken connected speech. The use of natural spoken English as an input language to computers will revolutionize the effectiveness and utility of computer systems. Speech is the only human output medium fast enough to keep up with thought processes and, as such, will permit a user to interact with a computer without the inevitable frustration and loss of time caused by current input devices. Furthermore, the use of spoken English would free the user's hands and eyes and could permit simple microphones and telephones to replace computer terminal input equipment.

This project involves research at all levels from analysis of the acoustic waveform and recognition of phonemes to syntactic and semantic content of English sentences. In the next fiscal year, limited but functional systems will be built and tested; each system will perform a specific task so that interpretation of the spoken input is simplified. Example tasks include spoken control of a simulated remote manipulator and answering spoken questions about a stored data base. These systems will have small initial vocabularies which will later grow to about a thousand words. These systems will be measured to ascertain how much computer power is required to attain real-time operation and to find the relationship between vocabulary size and numbers of errors. Major development of the grammar for spoken English will be completed, and the semantic routines which establish context and resolve ambiguity will be developed.



LOW MAINTENANCE RIFLE—A new rifle under development by ARPA is the so-called "low-maintenance rifle" which incorporates advances in aerospace materials and lubricants for frictionless operation. The new weapon is highly reliable.

Ground Combat Technology

In another less esoteric but nevertheless important area is ARPA's work in technology of weapons for the individual combat man. ARPA has, for example, explored new recoil mechanisms and barrel technology for lightweight weapons which have both area and point fire capabilities. Thus, one could have a single gun able to deliver an armor piercing antipersonnel multiple projectile as well as a high-explosive fragmenting grenade. Presently at least two separate weapons are required to achieve this versatility.

In another project, ARPA is working on advanced methods to improve the efficiency of light machine guns by a reduction in the number of gun parts and the use of plastic-encapsulated cartridges. A sliding breech weapon incorporating these features is currently under development and will be completed in FY 74.

Other work is concerned with the test and evaluation of previously developed low maintenance and liquid propellant weapons both to demonstrate the efficiency of these concepts and to determine their economic potential in terms of increasing the life of small arms and reducing both the cost of ammunition and logistical support requirements.

Another important advanced weapon concept is the Remotely Piloted Vehicle (RPV). Small, light, low cost RPVs are expected to direct tactical fire with great accuracy and flexibility. These miniature aircraft will carry television and night thermal imaging sensors to acquire targets and laser designators to enable precision guided munitions, missiles, and cannon-launched guided projectiles to attack hard targets with small warheads.

Armor Aspects

Some RPV components are being examined for use in an integrated fire control system for a tank. In this same connection, we are developing a new lightweight hypervelocity cannon to use various new types of ammunition to demonstrate the feasibility of operating as a dual-purpose anti-tank and anti-aircraft weapon. Emerging weapons technology such as open chamber and lockless breech mechanisms firing-out-of-battery, and constant recoil springs will enable development of a gun that is lighter in weight than the 105 mm gun on the M-60 tank. Furthermore, the rate of fire will be considerably increased. This high rate of fire when coupled with a multiple flechette round should provide an order of magnitude increase in capability over the VULCAN gun when operated as an AA system. A weapon of this type may enable the development of a dual purpose combat vehicle about half the size and weight of current tanks, which could replace both the M-60 tank and the VULCAN anti-aircraft gun. The weapon could also be applied to Marine Corps LVTs and Navy patrol craft. In FY 75, ARPA expects matching Service funds for demonstrations of these system concepts on combat vehicles.

Technological Assessment

Turning now to a different aspect of technological superiority, technology assessment, ARPA cannot maintain technological superiority without anticipating and confirming or disproving potential foreign weapons system developments.

Continued technological superiority of the U.S. involves not only hardware developments; it also involves the careful management of those technologies which provide us our lead. Movement toward providing U.S. technology to the U.S.S.R., the East European countries and the Peoples Republic of China (PRC) has been heightened by the exchange and export agreements entered into by the U.S. during the past year. The conflict between pressure for release of technology and concern over aid to a potential enemy can be reduced in large part by greater discrimination in the selection of items to be embargoed, and by a deeper understanding of the processes for technology use within the U.S.S.R., PRC and their allies, and, thereby assessment of the impact of any release. ARPA has begun a program to develop these two areas of knowledge. It includes a series of investigations of technology areas now on the embargo lists to select those items truly critical to retain, and secondly, the study of the processes for absorption and application of technology within these countries. The products of this work will not only be immediately valuable for judgments of strategic implications of technology considered for export or exchange but will also assist in providing us with the depth of understanding needed for critical judgments of the direction taken by Soviet military technology.

Future ARPA Programs
($ Thousands)

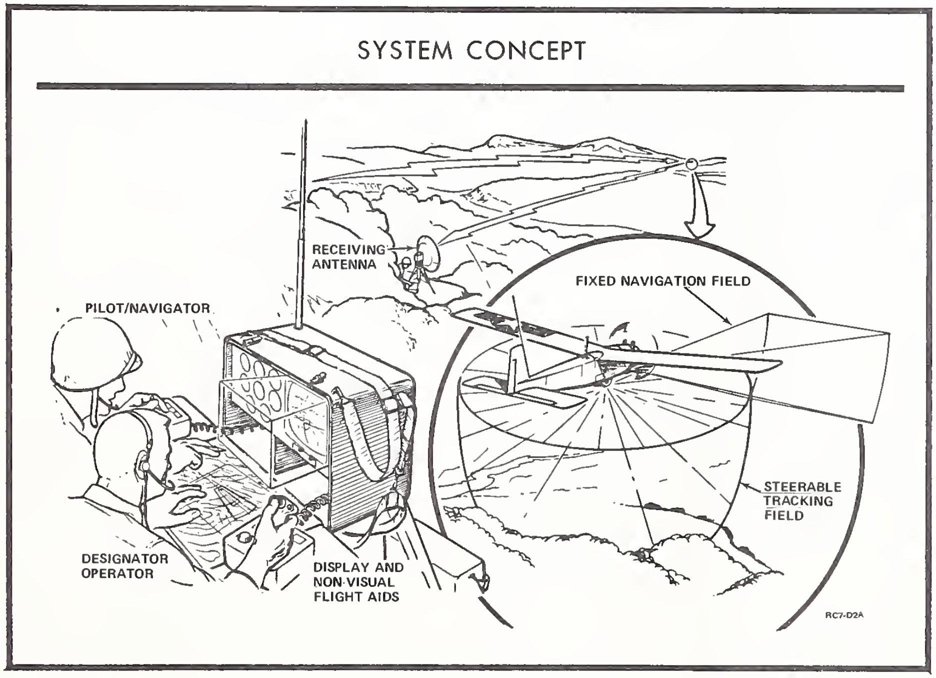
Title	FY 1973 Estimate	FY 1974 Proposed
DEFENSE RESEARCH SCIENCES	$35,269	$37,100
Materials Sciences	17,150	20,400
Power Systems Materials	4,290	6,880
Laser Component Materials	3,858	2,932
Structural Materials	2,853	2,504
Photoelectronic Materials	5,696	7,629
Other Materials Studies	453	455
Human Resources Research	3,800	2,800
Analysis of Complex Systems	1,300	0
Strategic Gaming and Simulation	400	600
Human Performance	2,100	2,200
Information Processing Techniques	14,319	13,900
Automation Programming	3,591	3,550
Picture Processing	2,500	2,509
Intelligent Systems	4,534	4,385
Speech Understanding	3,694	3,456
TECHNICAL STUDIES	$ 3,101	$ 4,000
STRATEGIC TECHNOLOGY	$70,765	$72,500
Advanced Strategic Concepts and Strategic Technical Analysis	4,711	4,930
High Energy Laser Technology	20,520	18,550
Midcourse and Special Infrared Optics	14,759	11,550
Advanced Concepts Technology	11,254	12,595
Surveillance Technology	6,652	5,070
Special Applications Technology	3,182	3,120
Strategic Space Technology	9,687	16,685
NUCLEAR MONITORING RESEARCH	$24,400	$21,400
Seismic Verification	10,119	10,435
Evasion Research	1,272	1,715
Nuclear Diagnostic Techniques	4,195	1,520
Physical and Chemical Diagnostic Techniques	1,445	0
Acoustic Array Signal Processing	3,185	4,330
Trace Element Detection	964	0
Military Use and Conservation of Resources	448	2,000
Technology Exchange	0	1,400
Vulnerability/Hardening	435	0
Fluid Injection/Waste Disposal	1,000	0
Environmental Research	1,337	0
TACTICAL TECHNOLOGY	$27,021	$27,600
Counterpart Development	1,704	0
Tactical Threat Analysis	845	600
Small Arms	1,983	1,500
Target Acquisition and Identification	2,918	3,650
Weapon Delivery Techniques	3,123	3,850
Advanced Concepts	853	900
Low-Cost Systems Technology	1,330	1,900
Tactical Systems Applications	3,222	3,200
Small Independent Action Forces	293	0
Marine Vehicles	2,935	2,800
Vehicle Research	450	3,300
Surface Effect Vehicles	3,676	2,400
Arctic Operations Technology	1,080	1,000
Ocean Monitoring and Control	2,489	2,500
Stabilized Floating Platforms	120	0
ADVANCED SENSORS	$ 8,200	$ 8,200
Optics Technology	4,585	4,500
Electronic Sensor Technology	900	900
Balloon Technology	2,265	1,900
Landbased Acoustic Surveillance Sensors	450	900
DISTRIBUTED INFORMATION SYSTEMS	$19,172	$20,300
Parallel Processing Applications	4,155	4,050
Distributed Networks	7,521	7,515
Climate Dynamics	3,341	3,310
Secure Systems	2,202	2,220
Sonar Signal Processing	434	0
Secure Voice Compression Techniques	1,519	3,205
ADVANCED COMMAND, CONTROL, AND COMMUNICATIONS TECHNOLOGY	$ 4,480	$ 9,800
Satellite Packet Technology	1,500	3,250
Ground Radio Packet Technology	1,730	3,850
Integrated Command and Control System Security	1,250	2,700
TRAINING, FORECASTING, AND DECISION TECHNOLOGY	$ 3,825	$ 6,200
Forecasting and Decision Technology	1,300	2,300
Advanced Training Technology	2,525	3,900
PROJECT MANAGEMENT SUPPORT	$ 3,558	$ 3,536
TOTAL	$199,791	$210,636

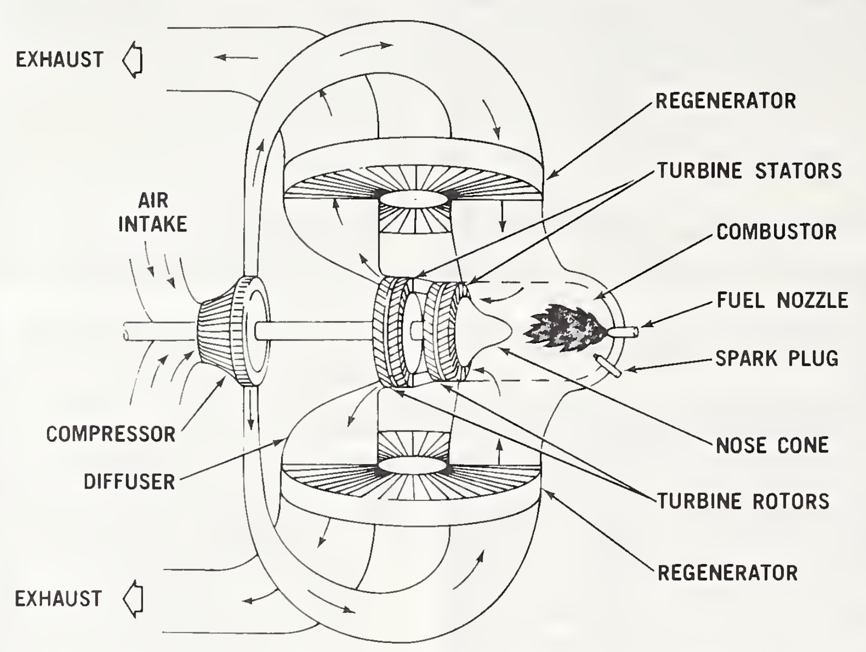
ARPA SHOW CASE

AND A LOOK AT SOME PROPOSED FY 1974 PROJECTS

Since its inception ARPA has used its resources to achieve a number of advanced research goals. Some of these [past] accomplishments were:

- Initiation of the U.S. space program in the immediate post-Sputnik era. This involved the initiation of programs in booster-technology, and satellite-technology for communication, navigation, and early warning, space surveillance, and manned space flight. When the National Aeronautics and Space Administration (NASA) was established in 1959, much of this work was transferred to that agency and most of the rest went to the Services.
- Defining the limits of seismic monitoring of a ban on underground tests and assessing the techniques whereby such a treaty might be evaded. In addition, ARPA has significantly improved the U.S. capability to monitor compliance with the limited test ban treaty, most notably by the successful development of satellite-borne sensors now incorporated in operational systems.
- Developed the field of re-entry physics in order to understand the phenomena attendant on the entry of a missile warhead back into the atmosphere. This has been fundamental to both the defensive problem (optical and radar discriminants) and the offensive problem (penetration aids and warhead vulnerability).
- Assured responsibility for major advances in radar technology such as large phased-array antennas and over-the-horizon radar techniques that are fundamental for ballistic missile defense, space surveillance, and early warning.
- Developed laser technology, in general and high energy laser technology in particular, that offers the prospect of an entirely new type of military capability.
- Initiated major development of sensors in the long wave infrared region of the electromagnetic spectrum and its application to such areas as mid-course discrimination, space surveillance, and Anti-Ballistic Missile (ABM) terminal homing.
- Made basic studies of the insurgent war and explored how the U.S. and foreign governments should organize their efforts to counter such a threat. This has ranged from such software efforts as analyses of the insurgencies in Malaysia, Philippines, and Thailand and lessons learned in Vietnam, to such hardware efforts as development of unattended ground sensors, foilage-penetrating radar, radio propagation in jungles, and assistance in the development of a military RDT&E capability in Vietnam, Thailand, Iran, Korea, and Turkey.
- Increased by a factor of about three the number of people trained in interdisciplinary materials sciences and raised the level of research activity by establishing twelve major university laboratories. Five other such laboratories were funded by NASA and the Atomic Energy Commission (AEC); DoD recently transferred responsibility for funding its laboratories to the National Science Foundation (NSF). Through this program ARPA has underwritten the development of the fundamental science that is the basis for Defense needs in sensors, electronics, power sources, structural materials, laser devices, etc.
- Enhanced the ability of people to use the enormous computational, memory, and logical capabilities of computers. This has taken the form of the development of computer timesharing, computer graphics, the interconnection of computers, advanced computer architectures, and artificial intelligence. The substantial current U.S. lead in computer technology is traceable, in part, to these innovations.
- Laid the foundation for the development of techniques and data bases for


SYSTEM CONCEPT



DOUBLE HORSEPOWER—A new gas turbine funded by ARPA is to be constructed entirely of ceramic components. Development of the turbine will permit a much higher temperature of operation which will lead to a significantly lower cost, a doubling of horsepower, an increase in efficiency, and the ability to use lower-grade fuels with cleaner exhaust emissions.

strategic forecasting and quantitative indicator systems to improve intelligence analysis procedures.

Recent Programs

Some more recent accomplishments of the ARPA program include:

- A simple speech understanding computer system has been demonstrated by an ARPA contractor. In a laboratory situation, commands spoken by several individuals using natural sentence structure but limited vocabulary were successfully understood and obeyed by a computer. This research in speech understanding by computer will greatly increase the accessibility and utility of future computer systems for all of the military Services.

- The ILLIAC IV computer system was installed at NASA's Ames Research Center. While checkout continues, operational use by defense contractors has begun. The ILLIAC IV is the most powerful computer now in existence; its speed will permit for the first time the solution of many complicated problems in aerodynamics, nuclear physics, and atmospheric simulation. Moreover, its unique parallel architecture is perhaps representative of the organization of future computers for defense applications. A translator has been developed which can automatically convert conventional sequential FORTRAN programs into parallel form for ILLIAC IV, thus avoiding the huge expense of manually restructuring existing computer programs.

- The computer resource-sharing ARPANET has also proven to be extremely effective for pure record traffic. A recent six-month comparative test by the Air Force showed the ARPANET to be twelve times faster and cheaper than other alternatives for logistics message traffic.

- Test and evaluation of the PLATO IV computer-based instructional system by the Army, Navy, and Air Force has progressed on schedule. The PLATO IV system is the most advanced computer-based instructional system in existence, and promises to provide a technology which could make a fundamental and favorable change in the productivity of the training process.

- Thirty successful flights have been completed in the ARPA Mini-RPV program, involving vehicles in the 40-70 pound class with 8-10 foot wing span. Small, lightweight, low-cost Remotely Piloted Vehicle (RPV) systems permit cost effective complements to manned systems for reconnaissance/strike and target designation functions in high threat environments. The mini-RPV is intended to demonstrate that militarily relevant functions can be accomplished with limited performance specifications and adaptation of state-of-the-art technology.

- A series of very long baseline interferometry experiments have been conducted using extra-galactic radio sources as a means of determining the distance between sites several thousand miles apart. This achievement should have an immediate impact on improvement of the earth-centered world geodetic system, serving the requirements for ballistic missile systems and aerospace defense.

- ARPA has made excellent progress in reducing to practice the theory of voice encoding. Recent experiments have shown that linear-prediction techniques make possible the transmission of high quality voice communications at data rates far below the conventional requirement for digital voice transmission. Data rate saving translates directly into cost saving.

- A very exciting scientific breakthrough came recently when a compound was synthesized which appears to have vanishingly small electrical resistance at a temperature as high as 60° K (Kelvin). This phenomenon, until now known only at temperatures near absolute zero, may have considerable practical importance. There are theoretical reasons to expect that superconductivity and recent breakthroughs will enable scientists to propose ways by which this may be done.

- Ceramic components for turbine engines have undergone successful initial tests. Processes for chemical vapor deposition of ceramic materials in rotor fabrication have been demonstrated. This program offers high potential for DoD to obtain higher efficiency, lower cost power sources without using critical materials. These engines will be non-polluting and can use residual fuels.

Proposed ARPA Program

The proposed ARPA program for Fiscal Year (FY) 74 is shown on Page 8 by program element. Overall, the program is proposed to increase by 5 percent from an FY 73 level of $199,791,000 to $210,-

636,000. Within this total program, the individual program elements vary, more widely reflecting both changing research opportunities and needs as well as organizational and management trends within ARPA.

For example, while research increases by about the same fraction as does ARPA as a whole, one notes that within the Defense Research Sciences funding in the materials area increases, while in the Human Resources and Information Processing Techniques area it decreases. The increase in the materials area is due to several causes. The high temperature ceramic turbine program was only partially funded in FY 73 in line with Congressionally-directed incremental funding policies. Full funding on essentially a fiscal year basis is resumed in FY 74. In addition, a new initiative in FY 73 to develop a new approach to night vision utilizing the 1.5-2 micron region of the nightglow spectrum requires a higher level of funding as that program comes up to speed.

The decreases in Human Resources and Information Processing Techniques reflect a slightly decreased emphasis on basic research in those areas, but these are somewhat counterbalanced by corresponding increases in the (6.2) part of the program where potential applications of this type of research are explored. For example, ARPA is decreasing basic work in speech understanding as it seeks to apply this to the specific problem of voice compression (in the Distributed Information Systems program element). This is important, not only because communication costs can be decreased, if we can reduce the bandwidth required to transmit speech, but also because, once digitized, the speech can be encrypted easily, thereby adding immeasurably to its security.

A similar situation occurs in the human resources area where basic work on the analysis of complex systems that has been supported for a number of years has been completed and the results are now available for application. This is typical of other research in the same area where ARPA feels that basic research results in areas such as forecasting and decision theory are not being adequately coupled into important aspects of defense. Consequently a new (6.2) program element in Training, Forecasting, and Decision Technology has been established to provide a focus for such efforts. The FY 73 funding shown in this new element represents on-going programs previously carried under 6.1 but now redirected to exploratory research. There is, in addition, some small program growth in this area as another FY 73 new initiative in advanced training technology reaches its planned level of expenditure.

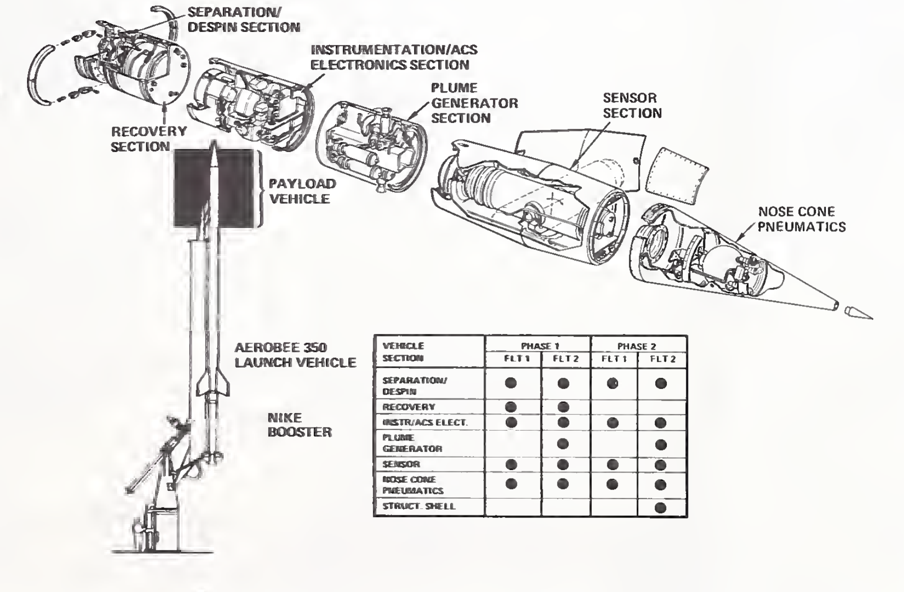
Another area where ARPA believes there have been important technological developments in programs that have not been adequately applied to an important defense problem is that of packet switching in communications. This technology which offers the potential for secure, reliable, and survivable communications that can be dynamically reallocated under crisis conditions has led us to establish a new program element in Advanced Command, Control, and Communications Technology for its exploitation.

As part of an internal shift in emphasis, ARPA has reorganized our work in tactical technology and for management efficiency have merged with it the work previously carried under the advancd engineering program element. This has enabled ARPA to centralize in a single group the entire range of tactical programs including both the land combat-oriented work previously carried in the tactical technology program element with a number of marine-oriented activities that made up the advanced engineering program. Similarly, the advanced sensors work has been divided between the tactical technology and the strategic technology program elements depending on whether the work had primarily a tactical or a strategic orientation. This change will be reflected in the FY 75 program but, since the reorganization occurred after the present program had been submitted, the advanced sensors program element remains as a budgetary but not as an organizational element within ARPA.

While not reflected in large changes in the overall levels, there are significant changes in the other program elements as well. For example, in strategic technology research [changes concern] over-the-horizon radar, longwave infrared optics, and high energy lasers which show decreases as these programs have either passed their peak funding levels or have entered a termination phase. On the other hand, an important new program initiated by means of an FY 72 reprogramming in the area of space surveillance and space object identification utilizing new techniques in coherent wideband radar processing and laser radar shows a significant increase.

Similarly in the nuclear monitoring area a number of programs in the area of nuclear diagnostics, trace element de-

SCOOP VEHICLE CONFIGURATION



VEHICLE SECTION	PHASE 1		PHASE 2	
	FLT 1	FLT 2	FLT 1	FLT 2
SEPARATION/ DESPIN	●	●	●	●
RECOVERY	●	●		
INSTR/ACS ELECT.	●	●	●	●
PLUME GENERATOR		●		●
SENSOR	●	●	●	●
NOSE CONE PNEUMATICS	●	●	●	●
STRUCT. SHELL				●

FLARE

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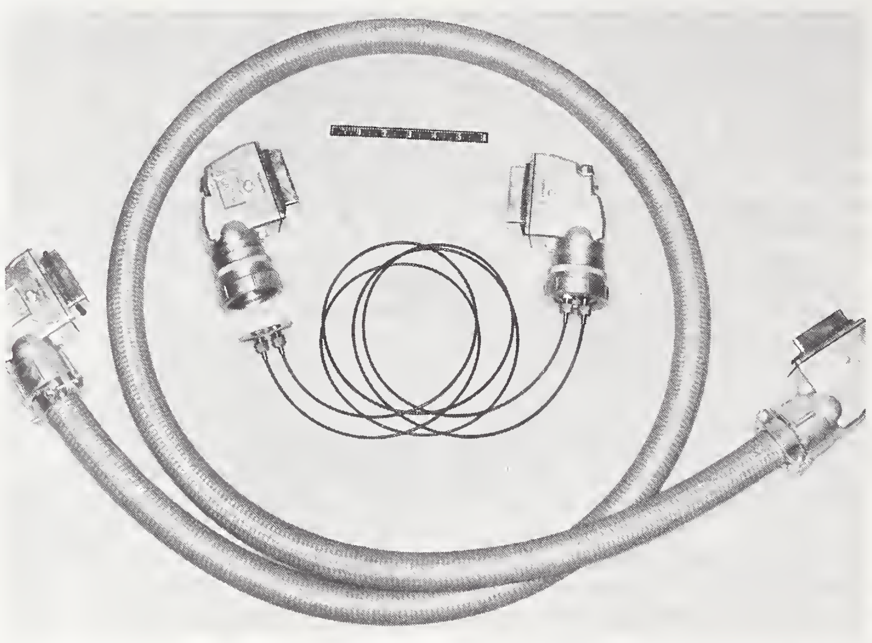

CABLE REDUCTION—Cable size can be reduced by replacing standard cable with an optical fiber. Within the input connector to the fiber cable is a light emitting diode (LED) and other circuits which convert the input electrical signal to a modulated optical signal from the LED. At the output end of the cable is a detector and amplifier which accomplishes the inverse function. The bandwidth and freedom from electrical noise for the optical fiber cable is greater than for the standard cable, while at the same time permitting a significant reduction in size and weight.

tection, and rock mechanics have been essentially completed. On the other hand, new programs in the military uses of critical energy resources and on the defense implications of technology exchange with the Soviet Union, Eastern Europe, and the Peoples Republic of China have been initiated.

Finally, the small increase in technical studies is the result of returning to full year funding of the Institute for Defense Analyses. Only partial funding was provided in FY 73 when this organization was put on a fiscal year basis at Congressional direction.

Management Philosophy

Primary emphasis in ARPA is given to the task of **maintaining technological superiorty.** ARPA understands this to mean three things. The first is the maintenance of leadership in forefront areas of technology so that DoD can be aware as soon as possible of developments of potential military relevance. In practice, ARPA selects areas of science and technology that might be expected to be relevant to military problems, such as material fabrication technology or infrared optics or ocean monitoring and supports them to the point where ARPA feels it has its potentially within the framework of currently understood problem areas.

Another aspect of technological superiority is the systematic development of advanced weapon concepts. This differs from the preceding in that here ARPA has a definite weapon concept in mind.

A third aspect of technological superiority is a continuing in-depth review of technology across-the-board, looking both for ways of applying known technology to our military problems and also ways in which this same technology could be applied by an adversary to the disadvantage of the U.S.

A second major problem area is that of the **maintenance of the U.S. strategic deterrent.** Emphasis in ARPA is primarily on the undersea deterrent and the associated question of antisubmarine warfare generally, since this is a system on which the Nation is placing increasingly heavy reliance and hence where an unexpected vulnerability could cause a particularly grave threat to our national security.

The third major problem is that of **increasing** the **efficiency** with which the Defense Department operates. This interest is driven in part by the obvious and inevitable limits on the amounts that we can allocate to defense, and in part it is motivated by the natural desire to do the best possible job with the resources available. The ARPA program addresses three areas where increases in efficiency would have a major impact. One of these is to develop technology that will lead to lower fabrication or operating costs. Another focuses on ways of increasing the reliability of military equipment. Another looks at ways of managing military manpower to enhance our utilization of this most important of our resources.

Finally, ARPA is involved in two problems that are especially important at the OSD level. One is the matter of command, control, and communications, the vital link between the central military and civilian authority in the Department and its operating elements. The other is a broad look at questions of surveillance and intelligence since this provides some of the fundamental perceptions on which key national security decisions are based.

COMMANDERS DIGEST

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